1-2-3 4-5-6 7-8-9 10-11-12-13 14-15 16-17-18-19 20

What is claimed is:

1. A method for generating digital filters for tuning a hearing aid to enhance hearing ability comprising:

providing first digital data (target curve) for a tolerance range for a target response curve representative of said enhanced hearing ability of sound level versus frequency;

providing second digital data (loss curve) representing an initial response curve of an initial hearing ability to be enhanced of sound level versus frequency;

comparing (FIG 10, 108) said first digital data to said second digital data and determining whether said initial response curve is within said tolerance range; and

if said initial response curve is not within said tolerance range, iteratively generating digital audio filters, applying said digital audio filters to said second digital data to generate third digital data for a compensated response curve, and automatically optimizing the frequency, amplitude and bandwidth of said digital audio filters until said compensated response curve is within said tolerance range or a predetermined limit on the number of digital audio filters has been reached, whichever occurs first. (page 34 - ln 15 - page 35 - ln 5)

2. A method according to Claim 1, wherein said step of iteratively generating digital audio filters is performed by iteratively generating second order filters. (see fig 5 and page 15 line 10 - 25)

3. The method of Claim 1 wherein said initial response curve is an audiogram. (see Fig 11)

4. A method for generating a set of second order filters to tune a hearing aid to enhance hearing ability comprising:

providing first digital data for a tolerance range for a target response curve representative of said enhanced hearing ability of sound level versus frequency;

providing second digital data representative of an initial response curve of an initial hearing ability to be enhanced of sound level versus frequency;

comparing said first digital data to said second digital data and determining whether said initial response curve is within said tolerance range; and

if said initial response curve is not within said tolerance range, generating a set of filters to tune said hearing aid by performing the following optimizing steps iteratively,

digitally processing said second digital data to determine an n^{th} (is channel) set of initial parameters for an nth peak in said actual initial curve where said initial response curve is not within said tolerance range, including a frequency, and amplitude and a bandwidth for said peak, where n is the number of an iteration of said optimizing steps, digitally generating a compensating nth filter from said n^{th} set of initial parameters, applying said n^{th} filter

to said second digital data and modifying said n^{th} set of initial parameters to determine an n^{th} set of optimum parameters for said compensating n^{th} filter, to generate third digital data for an nth interim compensated response curve of sound level versus frequency, processing said third digital data to determine whether said nth interim compensated response curve is within said tolerance range, if said nth interim compensated response curve is not within said tolerance range, performing another iteration of said optimizing steps until said interim compensated response curve is within said tolerance range or a predetermined limit on the number of filters has been reached, whichever occurs first. [illegible]

5. A method of Claim 4, wherein said step of digitally generating a compensating nth filter is performed by digitally generating a second order filter.

6. The method of Claim 4, wherein said initial response curve is an audiogram.

7. A method for generating filters for tuning a hearing aid to enhance hearing ability comprising:

providing first digital data for a tolerance range for a target response curve representative of said enhanced hearing ability of sound level versus frequency;

providing second digital data for an initial response curve of said hearing ability to be enhanced of sound level versus frequency;

comparing said first digital data to said second digital data and determining whether said initial response curve is within said tolerance range; and

if said initial response curve is not within said tolerance range, generating a set of compensating filters by performing the following single filter optimizing steps iteratively,

digitally processing said second digital data to determine an n^{th} set of initial parameters for an n^{th} peak in said initial response curve where said initial response curve is not within said tolerance range, including a frequency, an amplitude and a bandwidth for said peak, where n is the number of an iteration of said optimizing steps,

digitally generating a compensating n^{th} filter from said n^{th} set of initial parameters,

applying said n^{th} filter to said second digital data and modifying said n^{th} set of initial parameters to determine an n^{th} set of

optimum parameters for said n^{th} filter, to generate third digital data for an n^{th} interim compensated response curve of sound level versus frequency;

if $n > 1$, performing the following joint filter optimizing steps iteratively and cyclically,

generating fourth digital data for interim computed response curves in which for each joint filter optimizing iteration one of said n filters is absent, and then performing said single filter optimization steps utilizing said fourth digital data to generate fifth digital data for an updated interim response curve,

digitally processing said fifth digital data to determine whether the most recent of said joint filter optimizing iterations has resulted in a change in said updated interim response curve greater than a predetermined amount of change, and if so continuing to perform said joint filter optimizing steps;

processing said fifth digital data to determine whether said n^{th} interim compensated response curve is within said tolerance range, and if not,

performing another iteration of the foregoing steps until said interim compensated response curve is within said tolerance range or a predetermined limit on the number of filters has been reached, whichever occurs first,

but if so, ceasing performance of further iterations.

8. A method according to Claim 7, wherein said step of digitally generating a compensating n^{th} filter is performed by digitally generating a second-order filter.

9. The method of Claim 8 wherein said initial response curve is an audiogram.

10. A method for generating filters for tuning a hearing aid to enhance hearing ability of an individual comprising:

fitting said hearing aid to said individual; (See abstract)

(FIG 1) (26 R a)

connecting said hearing aid to a source of audio digital signals; (10)

(16, 20)

providing said individual with a device to generate indication signals at will;

(10)

generating and providing a first series of audio digital signals to said hearing aid, each signal in said first series of signals having a selected frequency and multiple power levels; (See page 38 ln 5 -16)

(16 to 20)

receiving said indication signal during said generation of a signal of a selected frequency indicative of said individual hearing said selected frequency; (See page 38 ln 18 - 26)

providing a digital audio processing unit in said hearing aid for processing received audio digital signals and providing processed audio

digital data, including applying digital audio filters for tuning said hearing aid characterized by coefficients in algorithms applied to said received audio digital signals to effect said digital audio filters; page 38 ln 27- pag 39 ln 10)

providing a digital computer (10) connected to receive said first series of audio digital signals and said indication (mouse) signals (m to generate digital data representative of said individual's hearing ability using said hearing aid without filters determined from said first series of signals, said computer programmed to determine said coefficients for digital filters for tuning said hearing aid and providing said coefficients to said digital audio processing unit in said hearing aid. (page 37 ln 7-23)

11. A method according to Claim 10, wherein said digital computer is programmed to determine said coefficients by

providing second digital data (target curve) for a tolerance range for a target response curve ability of representative of said individual's enhanced hearing ability of sound level versus frequency;

providing first digital data (loss curve) representative of an initial response curve of said individual's hearing ability of sound level versus frequency;

comparing (Fig 10 (1018) said second digital data to said first digital data and determining whether said response curve is within said tolerance range; and

if said response curve is not within said tolerance range,

iteratively generating coefficients (threshold) for digital audio filters,

applying digital audio filters determined by said coefficients to said first digital data to generate third digital data for a compensated response curve, and

automatically optimizing said coefficients by optimizing the frequency, amplitude and bandwidth of said digital audio filters until said compensated response curve is within said tolerance range or a predetermined limit on the number of digital audio filters has been reached, whichever occurs first. (page 36 ln 9 – page 37 ln 6)

12. The method of Claim 11 wherein said computer receives said first series of signals and indication signals generated by said device to generate said first digital date. page 37 ln 25 - page 38 ln 16.

13. The method of Claim 11 wherein said first digital data is an audiogram. FIG 11.

14. An apparatus for generating filters for tuning a hearing aid for use by an individual, comprising:

a sour~~ce of first au~~dio digital data; (FIG 11 (10)

a digital audio processing unit (1020) in said hearing aid for processing said first audio digital data and providing processed audio digital data to said individual, including applying digital audio filters for tuning said hearing

aid characterized by coefficients in algorithms applied to said first audio digital data to effect said digital audio filters; (col 13 ln 5-65)

pg 37 ln 9-23

a device for generating indication (16) signals indicative of said individual receiving said first audio digital data; and (pg 37 ln 25 - page 38 ln 5)

a digital computer (204) connected to receive said first audio digital data and said indication signals, said digital computer programmed to determine said coefficients for digital filters for tuning said hearing aid and provide said coefficients to said digital audio processing unit. (pg 38 ln 5-16)

15. An apparatus according to Claim 14, wherein said digital computer is programmed to generate second digital data representative of said individual hearing ability when using said hearing aid without filters determined from said first audio digital data and said indication signals and to determine said coefficients by

(target curve)

providing third digital data for a tolerance range for a target response curve of enhanced hearing of sound level versus frequency;

(loss curve)

providing said second digital data, wherein said second digital data represents an initial response curve of hearing ability of sound level versus frequency;

comparing said third digital data to said second digital data and determining whether said initial response curve is within said tolerance range; and (See FIG 10 1018)

if said initial response curve is not within said tolerance range,

iteratively generating coefficients for digital audio filters,

applying digital audio filters determined by said coefficients to said second digital data to generate fourth digital data for a compensated response curve, (FIG 11) and

automatically optimizing said coefficients by optimizing the frequency, amplitude and bandwidth of said digital audio filters until said compensated response curve is within said tolerance range or a predetermined limit on the number of digital audio filters has been reached, whichever occurs first. (page 36 l 9 - page 37 l 6)

16. A method for generating digital filters for tuning a hearing aid to enhance hearing ability, comprising:

providing first digital data FIG 11 (target curve) for a tolerance range for a target response curve representative of said enhanced hearing ability of sound level versus frequency;

providing second digital data FIG 11 (loss curve) representing an initial response curve of an initial hearing ability to be enhanced of sound level versus frequency;

comparing said first digital data to said second digital data and determining whether said initial response curve is within said tolerance range; and FIG 10 103

if said initial response curve is not within said tolerance range,

iteratively generating digital audio filters to compensate said initial response curve,

applying said digital audio filters to digital signals representative of received sound to generate third digital data, converting said third digital data to an analog signal and providing said analog signal to a speaker in said hearing aid,

generating fourth digital data representative of an enhanced response curve of hearing ability of sound level versus frequency;

comparing said first digital data to said fourth digital data and determining whether said enhanced response curve is within said tolerance range; and

automatically optimizing the frequency, amplitude and bandwidth of said digital audio filters until said enhanced response curve is within said tolerance range or a predetermined limit on the number of digital audio filters has been reached, whichever occurs first.

17. A method according to Claim 16, wherein said step of iteratively generating digital audio filters is performed by iteratively generating second-order filters.

18. The method of Claim 16 wherein said initial response curve is an audiogram.

19. The method of Claim 18 wherein said enhanced response curve is an audiogram.

20. A method for generating total log-integral metric digital data for characterizing the perceived performance of a hearing aid, comprising the steps of:

providing first digital data for N samples for a desired response curve of acceptable hearing ability of sound level versus frequency;

providing second digital data representing N samples for an initial response curve of sound level versus frequency; and

generating total log-integral metric data according to the formula:

$$M = \sum_{i=1}^{N-1} \log_{10}\left(\frac{f_{i+1}}{f_i}\right)\left[\frac{|S(f_i)_{dB} - D(f_i)_{dB}| + |S(F_{i+1})_{dB} - D(f_{i+1})_{dB}|}{2}\right]$$

where:

M is the total log-integral metric,

f is the frequency,

D is the first digital data,

S is the second digital data, and

N is the number of samples of first digital data and of second digital data.